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Review Article

Oral health and general health at the early stage of ageing: A review of contemporary studies

Shingo Moriya [a,*], Hiroko Miura [b]

[a] Health Promotion, National Institute of Public Health, 2-3-6 Minami, Wako-Shi, Saitama 351-0197, Japan
[b] Area of Community Healthcare, National Institute of Public Health, 2-3-6 Minami, Wako-Shi, Saitama 351-0197, Japan

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Summary In 2012, persons over age 65 reached 24.1% of Japan's population, and this population will continue to grow. The relationship between oral health and general health has been examined in many studies, geriatric dentistry in particular. An increasing need for long-term care for older adults is expected with the ageing of Japan's population. This will result in escalating costs for these services; thus, we are now prompted to identify predictors for eligibility for long-term care funding. Recent studies have revealed that many factors of oral health are associated with general health conditions. Of these, we focused on factors responsible for a decline in functional capacity that could facilitate long-term care certification. In the present review, we examine the relationships between oral conditions and general conditions, i.e. nutrition, physical performance, functional capacity, the need for long-term care, and longevity. Associations between oral and general condition have been established in many cross-sectional studies, and a number of longitudinal studies have shown associations between the need for long-term care, longevity, and some oral health factors including dentition status and masticatory ability. Further studies are required to show influence of oral health at the early stage of ageing on subsequent healthy life expectancy.

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* Corresponding author. Tel.: +81 48 458 6282; fax: +81 48 458 6288.
E-mail address: shyomi@niph.go.jp (S. Moriya).

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1. Introduction

Frailty is defined as a wasting syndrome associated with a decline in homeostatic capacities which leads to a significant increase in the age-related decline of different physiological systems, and then to disability, comorbidity, and the risk of death [1]. Disability in ADL is an adverse outcome of frailty that places a burden on care providers of frail elderly individuals and the care system. It is necessary to identify physical frailty indicators to predict ADL disability in order to prevent such disability or improve functioning in daily life. Recently, Vermeulen et al. systemically reviewed the literature on the predictive value of physical frailty indicators in ADL disability in community-dwelling elderly people, and concluded that physical frailty indicators such as weight loss, gait speed, grip strength, physical activity, balance, and lower extremity function are predictors of future ADL disability [2].

Such general health conditions are significantly associated with eligibility for long-term care funding for older people in Japan. Long-term care insurance (LTCI) system has made long-term care an explicit and universal entitlement for every Japanese citizen aged 65 and older, strictly on the basis of physical and mental status [3]. Although this system has grown rapidly, reflecting its popularity among seniors and their families, it faces several challenges, including skyrocketing costs. It is recommended to prevent older adults from becoming dependent while their need levels are still low by providing services intended to improve physical strength, nutrition, and also oral function [4].

Recent cross-sectional and longitudinal studies have shown that oral conditions are significantly related to general health conditions such as nutritional status, muscle strength, functioning in ADL, and care-need certification in older adults. These oral conditions include the number of natural teeth, occluding pairs of natural teeth, functional occlusion by dentures, perceived chewing ability (such as the number of chewable foods) and self-assessed masticatory ability. In addition to these observational studies, a few intervention studies reported that an improvement in oral conditions may have a positive influence on these general health conditions. It is possible that improving oral conditions may help prevent dependency in older adults through positively influencing general health conditions. These efforts should be addressed as early as possible in older adults, because healthy life expectancy is crucial for quality of life in ageing society. This review documents the available evidence of the relationship between oral and general health conditions focusing on nutrition, muscle strength, balance, functional capacity, the need for long-term care, and longevity at the early stage of ageing.

2. Oral conditions and nutrition

Individuals with fewer than 28 teeth reported a significantly lower intake of carrots, tossed salads, and dietary fibre than did fully dentate people; further, they had lower serum levels of beta carotene, folate, and vitamin C, indicating that dental status significantly affects diet and nutrition [5]. Although no statistical difference in BMI or intake of macronutrients was found between two groups of participants divided by occlusal status (a lost-contact group and a retained-contact group), the lost-contact group reported significantly lower consumption of vegetables and higher consumption of confectionery products (foods rich in sugar) than did the retained contact group; therefore they had a significantly lower intake of vitamin C and dietary fibre [6]. It can be concluded that a loss of natural tooth contact in the posterior region affects the intake of vitamins and dietary fibre. The mean intakes of some key nutrients and food groups, such as carotene, vitamins A and C, dairy products, and vegetables (including green—yellow vegetables), decreased with the increasing number of teeth lost, and mean intakes of carbohydrate, rice, and confectionery products were higher among those with fewer teeth [7]. These findings suggest that tooth loss leads to decreased consumption of fruits and vegetables but increased consumption of carbohydrates and confectionery products in older adults.

The dentate persons consumed significantly more fruits and vegetables, but the differences were not significant when juices were excluded [8]. If the diet of denture-wearers is to be improved, psychosocial factors and perceived chewing ability must be addressed because chewing ability explained approximately 4% of the variance in intake, and attitude, self-identity, and knowledge explained an additional 20% (approximately) [8]. The combination of tailored dietary interventions and replacement dentures can positively change dietary behaviour [9]. In this study, the intervention group ($n = 30$) received two dietary counselling sessions and the control group ($n = 28$) received current standard care. Perceived chewing ability increased significantly in both groups, but the dietary counselling group showed a greater increase in fruit and vegetable consumption than did the control group [9]. It is suggested that the consumption of fruits and vegetables is influenced by dental status or masticatory ability as well as attitude, self-identity, and knowledge. Although individuals wearing implant overdentures are significantly more likely to take in nutrients through fresh, whole fruits and vegetables than those with new complete dentures, there were no significant differences in nutritional state between the two groups as evaluated with blood nutrient levels [10].

A number of cross-sectional studies have shown a positive relationship between masticatory ability and serum albumin level. It was shown to be a significant nutritional indicator of decline in ADL and mortality [11]. A weak but statistically significant relationship was also found between self-assessed impairment of masticatory ability and lower levels of serum albumin in community-dwelling older adults [12]. Concentrations of serum albumin were well-correlated with chewing ability (evaluated by colour-changing gum) after adjusting

for age, gender, and muscle strength [13]. Significantly positive relationships were identified between dental occlusal conditions and nutritional status in older adults as evaluated by the Mini Nutritional Assessment (MNA) [14]. Six months after prosthodontic treatment, changes in body weight were significantly different between users and non-users regardless of denture type, and serum albumin levels were significantly increased among individuals using partial dentures in either or both jaws [15]. It is also suggested that prosthodontic treatment may improve the nutritional status of institutionalized older adults. No general improvement in nutritional status was observed since albumin and zinc levels and MNA values remained unchanged; pre-albumin levels even decreased, despite the highly significant improvement in masticatory ability after the optimization of the dentures [16]. Masticatory ability and efficiency are not the only factors affecting nutritional intake and status. Moreover, nutrition is not only a matter of masticatory function — it also depends on other influencing factors such as habits, taste, cultural customs, and financial and organizational considerations [16]. Overall associations between oral conditions and nutrition are shown in Fig. 1.

3. Oral condition and physical performance

Several epidemiological studies have identified relationships between oral conditions and physical performance parameters in community-dwelling older adults. Dental occlusal condition is positively associated with leg extensor power, stepping rate, and one-leg standing time with eyes open, indicators that evaluate lower extremity dynamic strength, agility, and balance function, respectively [17]. Perceived chewing ability (the number of foods considered chewable) is positively related to physical fitness measurements of leg extensor strength, one-leg standing time, or isokinetic leg extensors after adjustment for various confounding variables [18]. Self-assessed masticatory ability is significantly related to muscle strength and static balance functions, and the pattern of occluding pairs is significantly related to static balance function, particularly in older adults aged 65—74 [19]. Although handgrip strength was significantly lower in individuals who could chew only soft or pureed food than in those who could chew all textures of food, no significant difference was found in skeletal muscle mass between the three groups of masticatory ability [20]. Further, masticatory ability was significantly related to handgrip strength after adjusting for skeletal muscle mass, dentition status, and background factors, suggesting that chewing ability may be related to muscle strength independent of skeletal muscle mass [20]. After adjusting for age, gender, and body mass index, multiple regression analysis showed that severe periodontitis was significantly associated with poor physical performance, including handgrip strength and one-leg standing time with eyes open, in nonsmokers aged 55—96 years in Bangladesh [21]. These epidemiological findings suggest that oral conditions such as dentition status and perceived chewing ability may have an influence on certain types of exertion and physical performance in older adults.

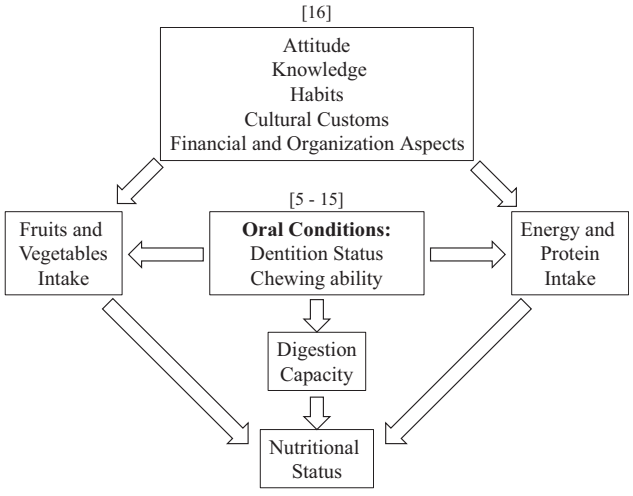

Figure 1 Oral conditions and nutrition. Overall associations between oral conditions and nutrition are concisely described in accordance with previous literatures in this area. The parenthesized number indicates number of the related reference.

Masticatory movements generate various orofacial sensory inputs via the trigeminal nerve, that is, the epithelial and periodontal mechanoreceptors, temporomandibular joint receptors, jaw-closing muscle spindles, and Golgi tendon organs [20,22—28]. Adjustments of motor output in response to changes in food hardness are largely mediated by feedback from periodontal receptors and muscle spindles of the jaw-closing muscles [28]. It is not certain that peripheral sensory inputs are the only reason for the association demonstrated; central mechanisms may also play a role. Given that previous studies have identified an association between limb and orofacial motor control mechanisms [20,29,30], it is possible that peripheral orofacial sensory inputs may influence motor-neuronal control of muscle exertion in other parts of the body.

Appropriate models of postural control in older adults consider visual, vestibular, somatosensory, and musculoskeletal functions, which are integrated under higher cortical or central influences [31]. Several studies have shown that occlusal relationships and jaw position affect neck muscle activity [32—34], trunk muscle activity [35], head position [36], and balance [37,38]. It has been shown by experimental studies in human that voluntary teeth clenching influenced the amplitude of the soleus H reflex and attenuated reciprocal inhibition from the pretibial muscle to the soleus muscle [39,40]. These findings suggest that oral motor activity in the jaw may influence the motor activity of the other parts of the body.

In a 3-year longitudinal cohort study (the Aichi Gerontological Evaluation Study) of 1763 community-dwelling individuals aged 65 years and older, logistic regression models adjusted for all covariates showed that subjects with 19 or fewer teeth who did not use dentures had a significantly increased risk of incident falls compared with those having 20 or more teeth. Among subjects with 19 or fewer teeth, the risk of falls was not significantly elevated as long as they wore dentures [41]. It was found that functional dental occlusion (natural teeth and dentures) was significantly associated with the frequency of falls in older adults with dementia during the previous year, and that denture treatment for participants with functionally inadequate occlusion was associated with a reduced incidence of falls during the 1-year investigation period [42]. Improved physical performance

was not observed for the entire study population following dental treatment; however, times for one-leg standing with eyes open increased significantly in subjects with improved masticatory ability in a intervention study for community-dwelling older adults [43]. Therefore, it is possible that dental treatment to maintain occlusal contact, good masticatory ability, and functional occlusion may contribute to maintaining balance and further prevent incident falls or accidents in older adults. The important findings from those studies are concisely shown in Fig. 2.

4. Functional capacity, the need for long-term care, longevity, and oral conditions

A number of cross-sectional studies have shown relationships among functioning in ADL, higher-level functional capacity, and masticatory ability. Perceived chewing ability was positively associated with independence level (evaluated as independent, home-bound, or bedridden) and total Tokyo Metropolitan Institute of Gerontology (TMIG) index scores [44]. Logistic regression analysis revealed that functional dependency was 7.5 times more prevalent in individuals capable of chewing four or fewer foods, and 3.3 times more prevalent in those chewing five to nine foods than in those able to chew all 15 items, suggesting that chewing ability may be independently related to functional status in 80-year-olds [45]. High-level functional capacity including intellectual activity and social role in middle-old elderly individuals was associated with the ability to chew hard foods [46]. Significant differences were found in the total score and sub-scores of intellectual activity and social role on the TMIG index among the three groups of self-assessed masticatory ability [47]. Multivariate logistic regression analysis showed that severely impaired masticatory ability (the ability to chew only soft and pureed food) was significantly related to a loss of three or more points from the total score, and the loss of one point or more for intellectual activity and social role after adjustment for age, gender, household, educational background, and medical condition [47]. Therefore, masticatory ability may be a significant indicator of functional capacity, i.e. basic ADL and high-level functional

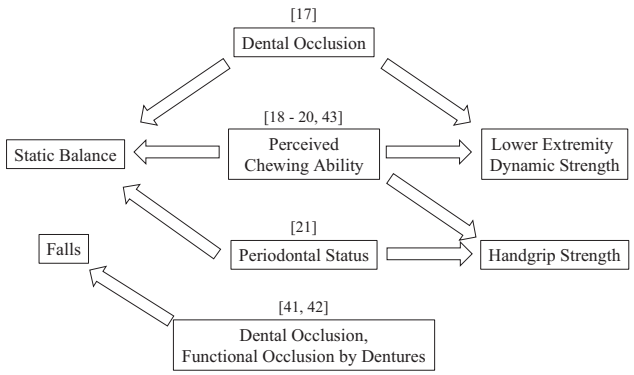

Figure 2 Oral conditions and physical performance. Important findings regarding to associations between each oral condition and physical performance are shown on the basis of results from cross-sectional, longitudinal, and intervention studies previously reported. The parenthesized number indicates number of the related reference.

capacity, especially intellectual activity and social role. The relationship between masticatory ability and functioning in basic ADL could be explained by a possible mechanism through which masticatory ability positively influences physical performance. Regarding the relationship between masticatory ability and high-level functional capacity (i.e. intellectual activity and social role), it is possible that dental health behaviours may contribute to maintaining good oral health and the resulting good masticatory ability, and higher-level functional capacity may be an accurate indicator of dental health behaviours in community-dwelling older adults [48].

The influence of dental treatment on oral health-related quality of life and functioning in ADL was demonstrated in an intervention study on institutionalized Japanese older adults [49]. The participants were allocated into intervention and control groups. The intervention group, which had received dental treatment, showed significant increases in GOHAI scores between baseline and six weeks, whereas no significant difference was found between baseline and six weeks in the control group. The differences in the changes in FIM scores for expression were significant in the model adjusted for covariables, suggesting that dental treatment improved oral health-related QOL and the expression function of ADL [49].

In a large scale epidemiological study, physical ability in edentulous subjects without dentures significantly deteriorated compared with that of dentate subjects with 20 or more teeth [50]. Further, the 6-year mortality rate of the edentulous subjects without dentures was significantly higher than that of the subjects with 20 or more teeth [50]. Poor dentition status, especially edentulousness without dentures, may therefore be related to deterioration in older adults' systemic health. In one 4-year prospective cohort study, dentition of fewer than 20 teeth was associated with the onset of physical or cognitive disability even after adjustment for age, sex, self-rated health, present illness, BMI, smoking history, alcohol consumption, exercise, and equivalent income [51]. In addition, this study is the first to examine the association between eating ability and disability. The results showed a greater onset of disability in older adults with eating difficulties, but this association was explained by demographic, socioeconomic, behavioural, and general health factors [51].

Among participants aged 65—79 years, the frequency of care-needs certification was significantly higher in those with poor or fair masticatory ability than in those with good masticatory ability [52]. The relative hazard ratio was also significantly higher in those with poor or fair masticatory ability than in those with good masticatory ability after adjusting for age, gender, current employment status, educational background, social interaction, chronic medical conditions, and dentition status [52]. These relationships were not found among those aged 80—93 years. Impairment in perceived chewing ability may be associated with a higher incidence of certification in Japan's long-term care insurance system among elderly persons.

There are many studies which show that mortality is significantly associated with dental status, perceived chewing ability, and the utilization of dentures. In a large-scale longitudinal study with a 57-year follow-up period, although no substantial association was found between the number of

missing teeth (as a continuous variable) and all-cause mortality, there was evidence that subjects with nine or more missing teeth at baseline had an increased risk of cardiovascular disease [53]. Complete edentulism prior to 65 years of age was associated with all-cause mortality after multivariable adjustment for several socioeconomic characteristics over a 16-year follow-up period [54]. Tooth loss is a significant predictor of mortality independent of health factors, socioeconomic status, and lifestyle in octogenarians, with a stronger association in women [55].

In a survey of a population of 80-year-old community residents, the ability to chew the fewest types of food was associated with a higher risk of mortality than that of those with the ability to chew all 15 types of food [56]. Self-assessed masticatory disability remained a significant predictor of 9-year mortality in a cohort of community-residing older adults [57]. Survey respondents reporting the lowest number of chewable foods were associated with a higher risk of cardiovascular mortality than those who were able to chew all types of food in a prospective study of 697 80-year-olds [58]. Women aged 40 years or older with fewer than 10 functional teeth and without dentures showed a significantly higher mortality rate than those with dentures during a 15-year follow-up period [59]. In healthy independent older adults aged 65 or over, poor dental occlusion was associated with an increased risk of mortality; in the edentulous, and the use of dentures was associated with a decreased risk of mortality [60]. Denture use was shown to be a significant indicator of perceived chewing ability in older adults without occluding pairs of natural teeth [61]. These findings suggest that poor dentition status, the lack of denture use in a person with few natural teeth, and impaired masticatory ability may be significant factors associated with increased mortality.

5. Conclusion

(1) Masticatory function is significantly associated with nutritional intake and status at the early stage of ageing adults. Other influencing factors should be considered to approach nutritional problems as well.
(2) Relationships between oral conditions and physical performance have been established in cross-sectional, longitudinal, intervention, and also experimental studies.
(3) Some oral conditions may be associated with functional capacity, the need for long-term care, and longevity in older adults.
(4) Further studies are required to show positive influence of oral health at the early stage of ageing on subsequent healthy life expectancy.

Conflicts of interest

The authors have no conflicts of interest to declare.

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